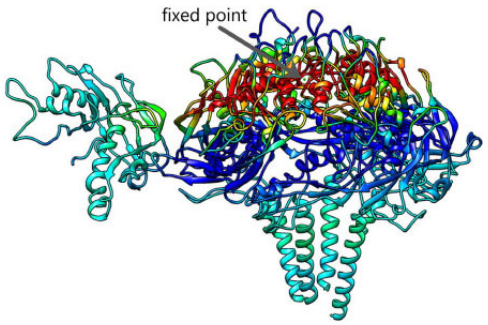
CornellEngineering
Meinig School of Biomedical Engineering

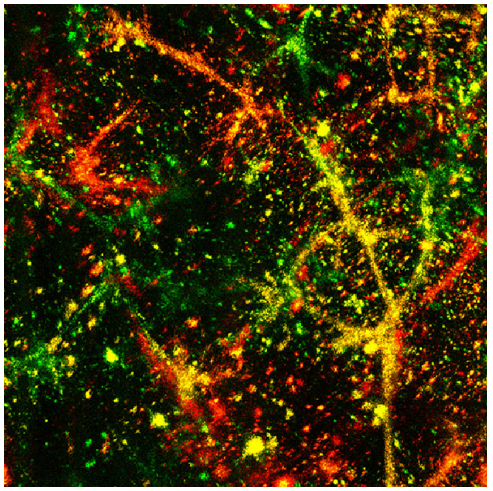
Biomedical Imaging & Instrumentation

The pioneering work determining the biological mechanisms of disease and the lifesaving work of diagnosing and treating medical problems rely on sophisticated imaging techniques developed by engineers. At Cornell, collaborations among engineers, physical scientists, life scientists and clinicians provide superb opportunities to create and improve these tools. BME faculty focus on time-resolved and spectrally-resolved measurement and visualization of biological structures across scales, with spatial scales ranging from macromolecular complexes to cells to whole organisms, temporal scales ranging from milliseconds to years, and spectral scales ranging from megahertz radiofrequency waves to exahertz x-rays.

A wide range of imaging modalities and methods for achieving contrast are developed and used, including optical imaging, MRI, and CT. Cornell is known for pioneering development and application of nonlinear optical imaging techniques for in vivo imaging and our researchers are also inventing new image analysis methods and novel contrast agents for clinical and research use. BME faculty apply these imaging tools to a diverse set of human health problems including neurodegenerative disease, cancer, and heart disease. Biomedical imaging is also interconnected with other areas of BME, providing in vitro and in vivo tools to evaluate biomaterials, validate systems biology models, monitor drug delivery, and map biomechanical properties.



Ribbon diagram of one asymmetric unit of bacteriophage HK97 colored by the covariance function between the indicated fixed point and all other locations all from single-particle cryo electron microscopy. (Doerschuk)



Volumetric OCT reconstruction of an NIH-3T3 fibroblast cluster in Matrigel, showing computed cellular resolution over a 400 um depth range. False color encodes depth. (Adie)

Faculty research interests

Steven Adie's lab develops optical coherence tomography (OCT)-based methods for 4D imaging of biophysical cell-matrix mechanical properties, including methods for high-resolution imaging of soft tissue biomechanics. These new capabilities support collaborative studies on the role of biophysical factors in physiological processes (e.g. stem cell function) and disease (e.g. cancer). His group also develops new image formation paradigms for OCT by synergistically combining physics-based computed imaging techniques and hardware adaptive optics. These approaches are used to extend the spatiotemporal coverage and imaging depth of OCT, and have applications to ultra-deep multimodal imaging of neural network activity in animal models.

James Antaki's research involves development of diagnostic devices for the home and point-of-care to improve patient engagement, currently focusing on diabetic foot ulcers and breast lesions. He is also developing clinical decision-support tools for severe heart failure, based on deep-learning statistical models to predict the risk of adverse events for various clinical interventions, such as heart-assist devices.

(Over)

Jonathan Butcher's lab applies different imaging modalities to study embryonic morphogenesis, the dynamics of cardiac function and small animal models of congenital and acquired cardiac disease. His lab uses multiphoton microscopy, high frequency ultrasound and micro-CT to investigate cardiac structure-function dynamics in living embryonic and adult model animals.

Nate Cira's lab leverages microscale fluid physics and capillarity and wetting to develop microfluidic devices. Past work has included explorations of droplet/surface interactions and creation of self-loading devices to evaluate antibiotic resistance. This foundation is currently being applied in the lab to create high throughput fluidic devices with advanced liquid handling capabilities.

Iwijn De Vlaminck's research focuses on the development of molecular analysis technologies for microbiology and immunology and the application of these technologies in the monitoring of infectious diseases and immune-related complications. His research is highly interdisciplinary in nature, and requires innovation in genomics, computational biology and molecular engineering.

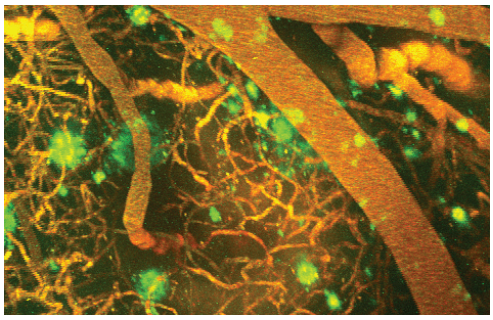
Peter Doerschuk's group develops quantitative image and signal analysis algorithms using ideas from statistics, machine learning, and high performance computing and applies them to a diverse set problems, for instance, determining the 3-D reconstruction of biological and synthetic nano particles from 2-D electron microscopy images.

Nozomi Nishimura's lab is interested in understanding how inflammation, blood flow and cell death are linked in several different diseases. The strategy is to develop novel tools such as multiphoton microscopy to image the contribution of multiple physiological systems to diseases with in vivo animal models. The lab uses these new vivo optical imaging developments in mouse models to study the diversity of cellular phenotypes and structures in a whole living organism. Targeted applications include heart disease, neurodegeneration and stem cells in the intestine.

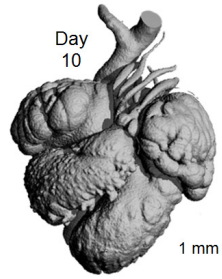
Chris Schaffer's lab employs light not only to visualize biological systems, but also for targeted ablation and manipulation. For example, using extremely short laser pulses, Schaffer's lab causes localized injuries to individual blood vessels in the brains of rodents, triggering a small stroke. These targeted microstrokes allow the lab to study the role of microvascular lesions in neurodegenerative diseases such as Alzheimer 's disease.

Yi Wang's lab develops MRI methods using tools from computer science, mathematics, and physics, and knowledge in biology, chemistry and medicine. His lab pioneers quantitative susceptibility mapping (QSM), quantitative transport mapping (QTM), superresolution 4D imaging, and multi-scale imaging by integrating MRI with optical microscopy, and works closely with clinicians on diagnosing and treating various diseases, including heart diseases, neurodegenerative diseases, multiple sclerosis, vascular diseases, and cancers in the breast, liver and prostate.

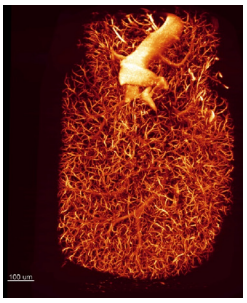
Warren Zipfel's lab develops and applies novel methods of fluorescence microscopy and bioanalytical techniques. He was involved in the early development and commercialization of multiphoton microscopy at Cornell and continues to apply multiphoton, as well as confocal and super-resolution microscopies, in a variety of research areas ranging from transcriptional regulation & 3D nuclear structure to cancer biology.



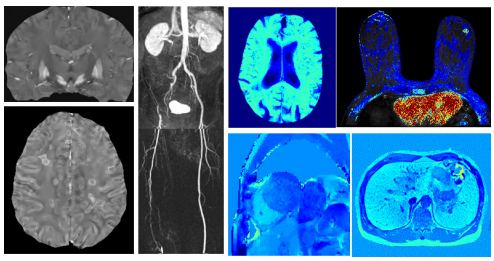
Imaging Alzheimer's disease: Blood vessels (yellow) and amyloid plaques (green), the hallmark of Alzheimer's disease, imaged in a mouse brain. (Schaffer)



µCT reconstruction of a day 10 embryonic chick heart. (Butcher)



Nano-CT image of the vasculature of a mouse liver taken at 700 nm resolution. (Cornell Imaging Facility)



QSM (column 1) to map deep brain stimulation (DBS) target (top) and multiple sclerosis (MS) lesion (bottom), MR Angiography (C2) to map vascular occlusion, oxygen extraction fraction (C3) to map lesion in stroke (top) and blood oxygenation (bottom), and functional characterization (C4) to characterize breast cancer (top) and liver iron metabolism (bottom). (Wang)

BME department faculty

Steven Adie, sga42@cornell.edu
James Antaki, jfa79@cornell.edu
Jonathan Butcher, jtb47@cornell.edu
Nate Cira, njc222@cornell.edu
Iwijn De Vlaminck, id93@cornell.edu
Peter Doerschuk, pd83@cornell.edu
Karl Lewis, kjl235@cornell.edu
Nozomi Nishimura, nn62@cornell.edu
Chris Schaffer, cs385@cornell.edu
Yi Wang, yw233@cornell.edu
Warren Zipfel, wrz2@cornell.edu

Graduate field faculty

Susan Daniel, sd386@cornell.edu
David Erickson, de54@cornell.edu
Lara Estroff, lae37@cornell.edu
Jack Freed, jhf3@cornell.edu
Jesse Goldberg, jesse.goldberg@cornell.edu
Daniel Heller, dah368@cornell.edu
Brian Kirby, bk88@cornell.edu
Amit Lal, lal@ece.cornell.edu
Manfred Lindau, ml95@cornell.edu
Christiane Linster, cl243@cornell.edu
Frederick Maxfield, frmaxfie@med.cornell.edu
Alyosha Molnar, molnar@ece.cornell.edu
Jeffrey Moses, moses@cornell.edu
Susan Pannullo, scp2002@med.cornell.edu
Matthew Paszek, mjp31@cornell.edu
Lois Pollack, lp26@cornell.edu
Anthony Reeves, apr5@cornell.edu
Mert Sabuncu, msabuncu@cornell.edu
Alexander Travis, ajt32@cornell.edu
Melissa Warden, mrwarden@cornell.edu
Alan Weinstein, mweins@med.cornell.edu
Ulrich Wiesner, ubw1@cornell.edu
Mingming Wu, mw272@cornell.edu
Chris Xu, cx10@cornell.edu
Ramin Zabih, rdz@cs.cornell.edu

www.bme.cornell.edu